Low cost low tech (LCLT) sensors: Field Evaluations and multi-sensor approaches for emissions factors

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What is Meant By:

- **Low-Cost**
  - 100's of $'s

- **Low-Tech**
  - Existing Technology
  - Tried and True Technique

'Airpocalypse' Hits Harbin, Closing Schools

(Mia Li, NYT, Oct. 21, 2013)

# Beijing to more accurately monitor air quality

By LOUISE WATT | Associated Press – Sun, Oct 7, 2012

BEIJING (AP) — Beijing authorities have completed a network of monitors that will more accurately measure air quality in the smog-ridden city after being pushed into it by public pressure and pollution reports from the U.S. embassy.

The Beijing Municipal Environmental Monitoring Center said Saturday that another 15 monitoring stations had begun releasing real-time data on small particulates known as PM2.5. The tiny pollution particles that may result from the burning of fuels in vehicles and power plants can penetrate deep into the lungs, so measuring them is considered a more accurate reflection of air quality than other methods.

Chinese citizens have prodded their government into publishing more detailed pollution data since the U.S. Embassy started publishing PM2.5 readings taken from its rooftop on Twitter.
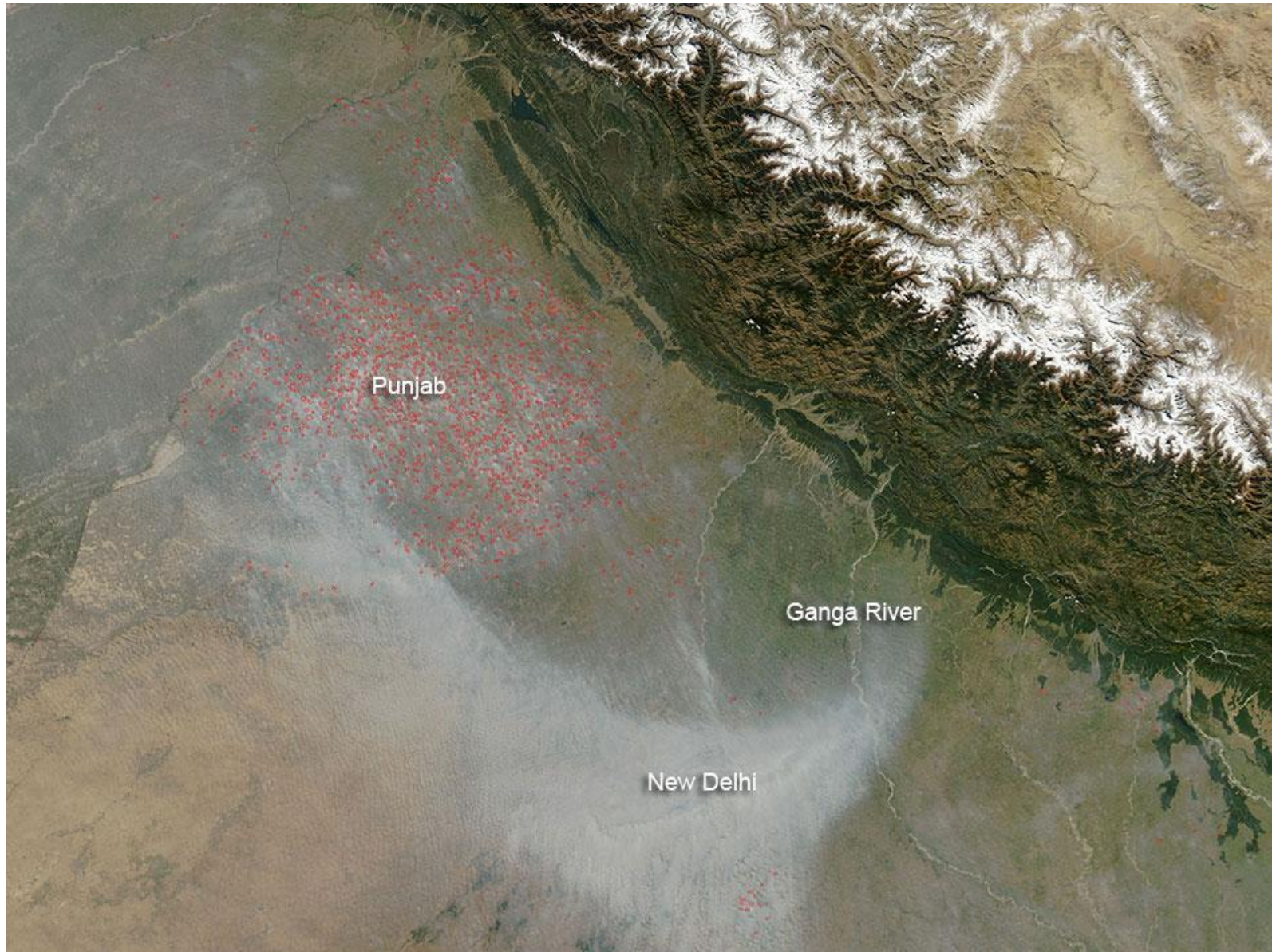
Global Burden of Disease

(Lancet, 2012)
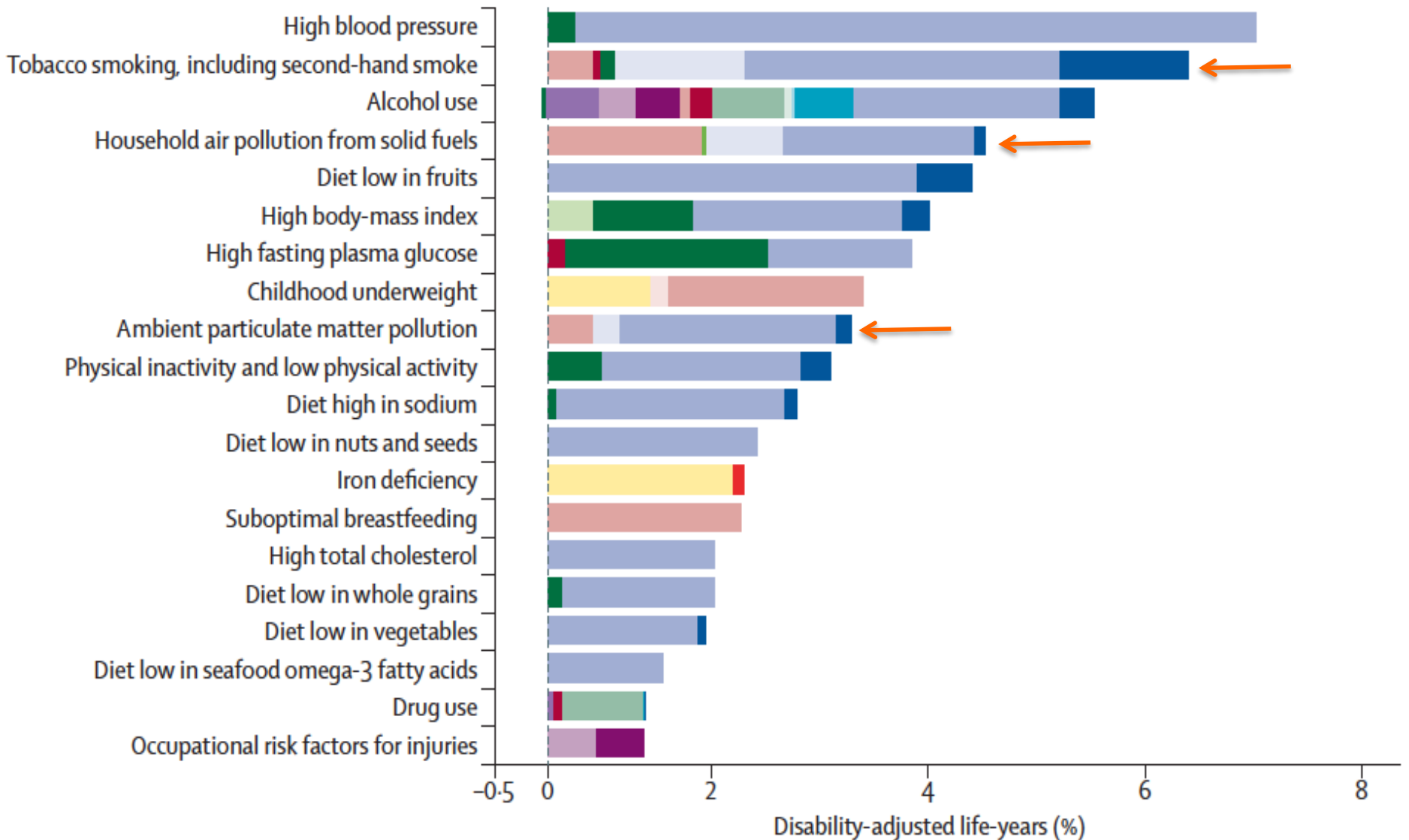
Household Cooking in LDR's

(Aprovecho, 2008)

PM of 1000 ug m^{-3} Last Winter in India
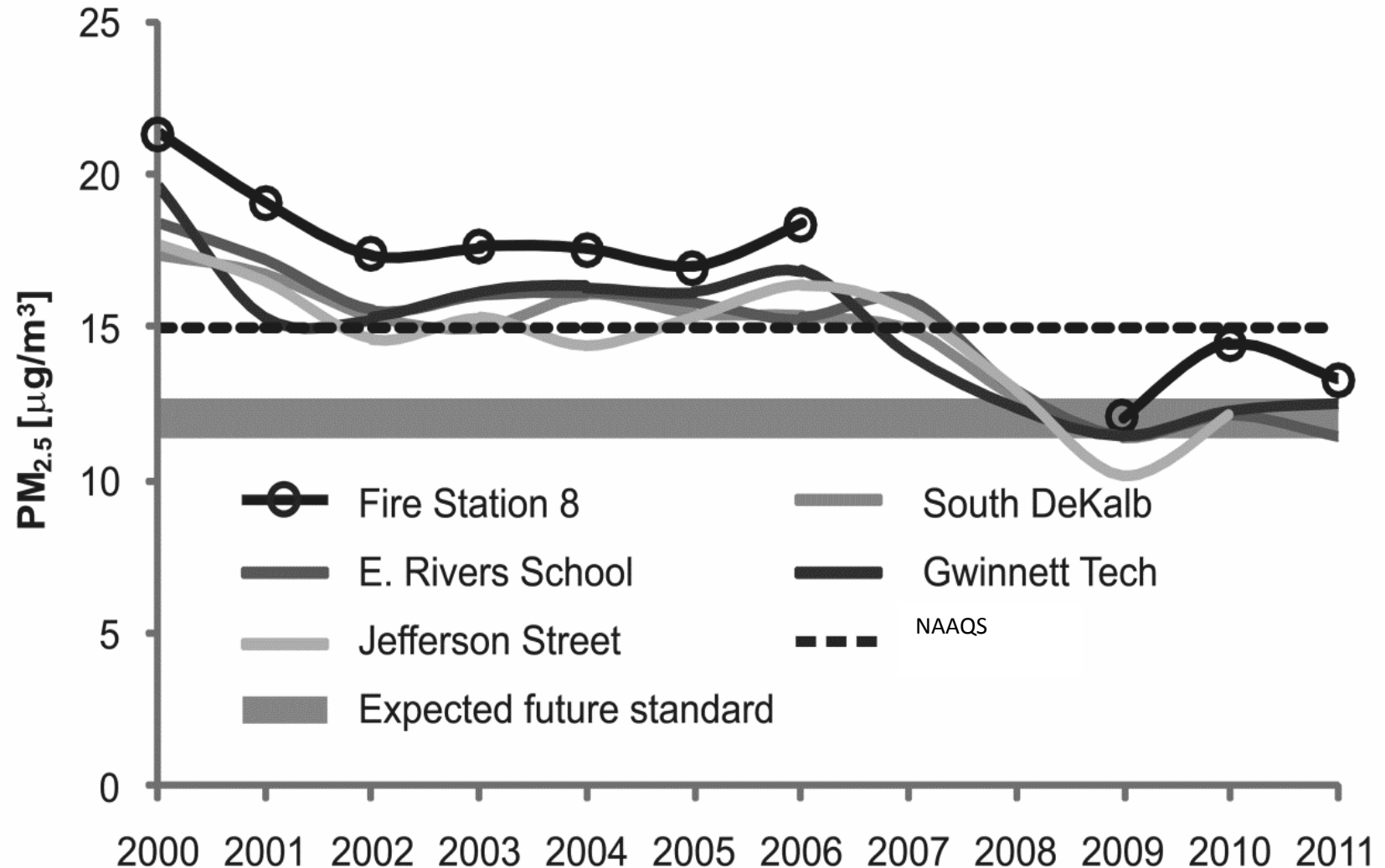

(NASA; October 31, 2012)

Atlanta, Ga

Why Do We Need Sensors?

- **Enhance our understanding of temporal and spatial variability of PM**

- **Better estimate personal exposure to PM**

- **Determine emissions and sources of PM**

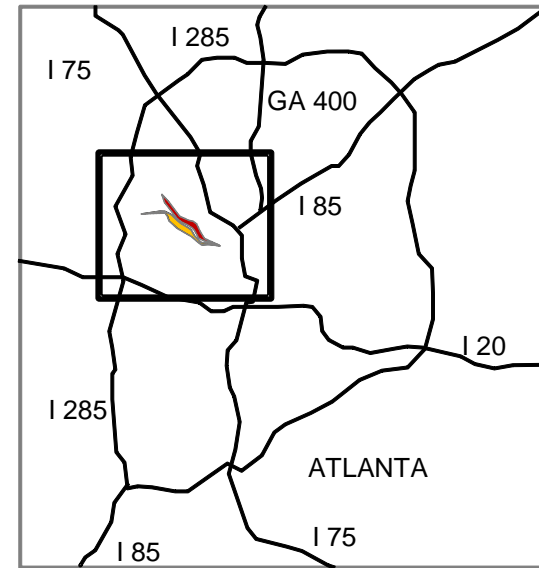- **Supply critical air quality information to policy makers and the public**

Typical Air Quality Monitoring Station in the US

www.eec.ky.gov

PM$_{2.5}$ Trends In Atlanta

Railyard Location

- **Inman and Tilford Railyards are located in urban Atlanta**
- **Fire Station 8 (FS) Georgia EPD monitoring site on the edge of the yards**

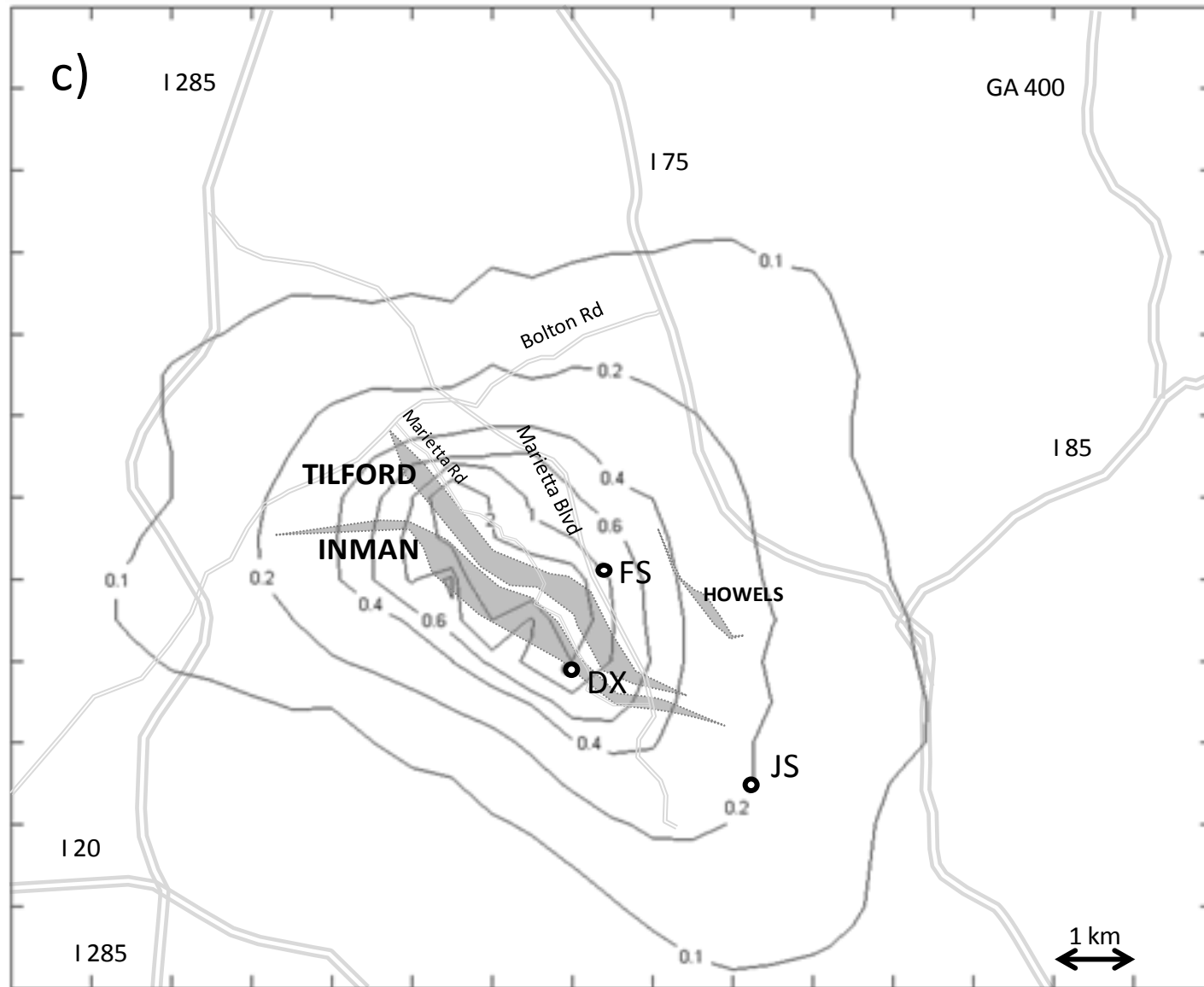# Determining Railyard Emissions with Monitoring Stations

- **CO_2 (Thermo 41i Analyzer)**
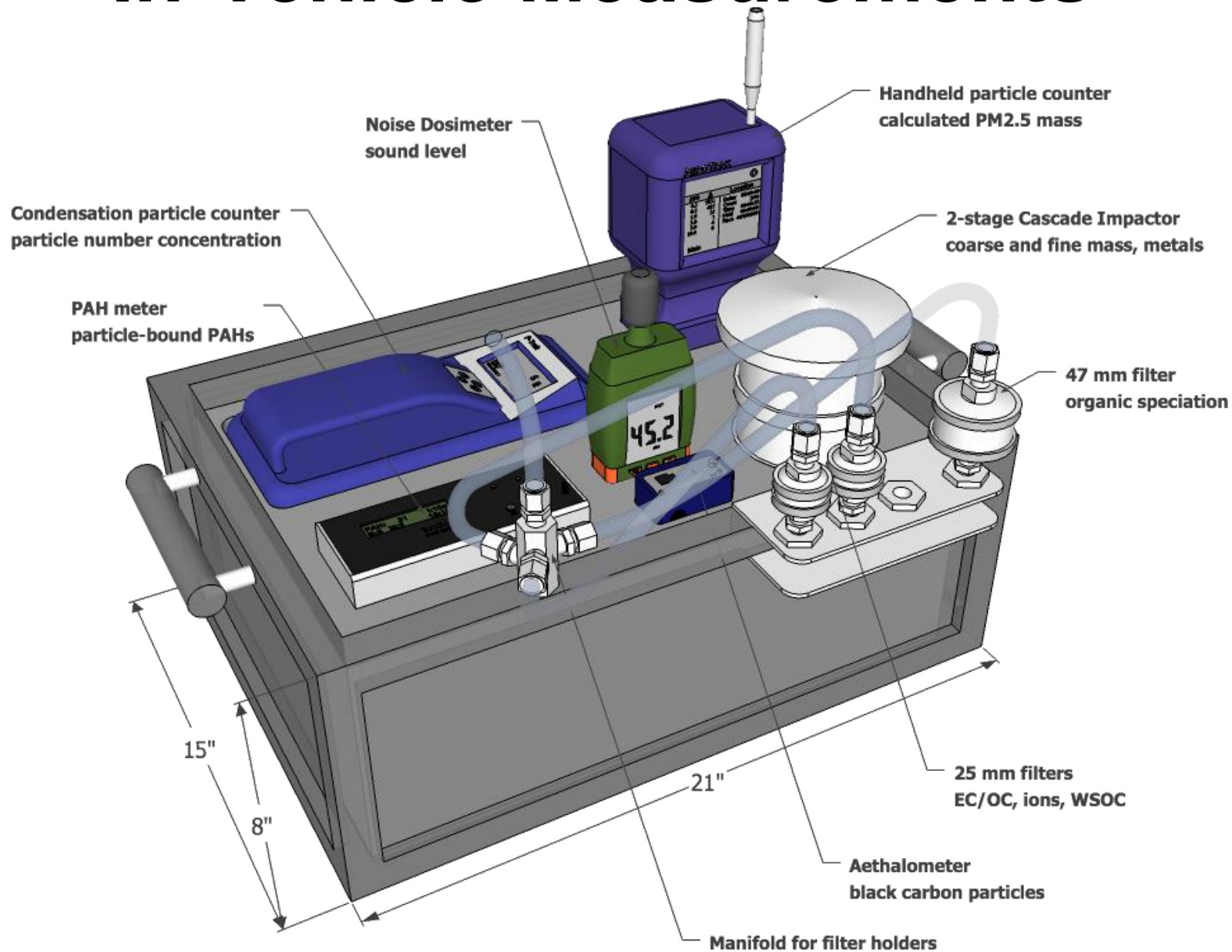- **BC (Thermo MAAP Analyzer)**
- **$PM_{2.5}$ (R&P TEOM Analyzer)**

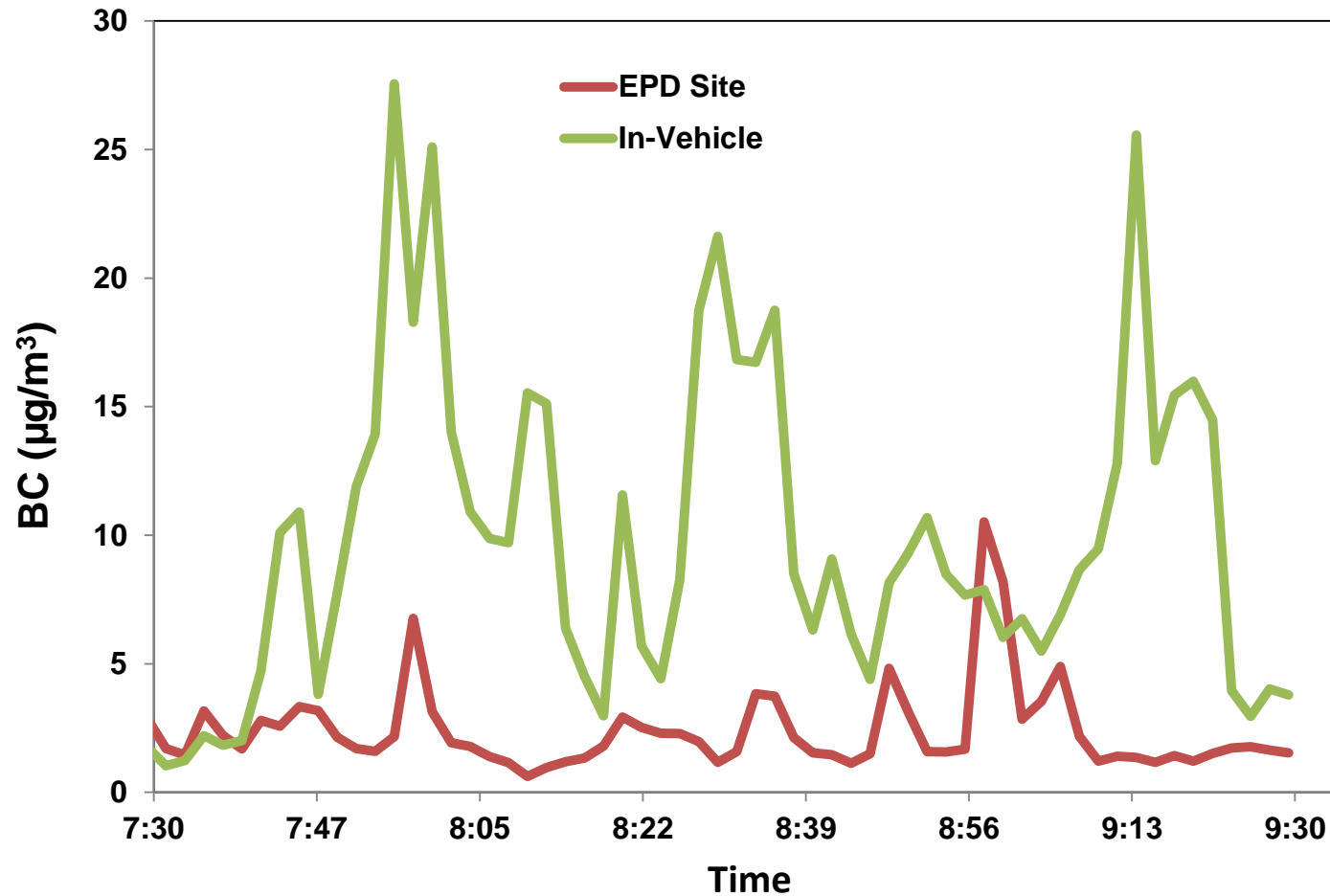# BC Events (Slope Method)
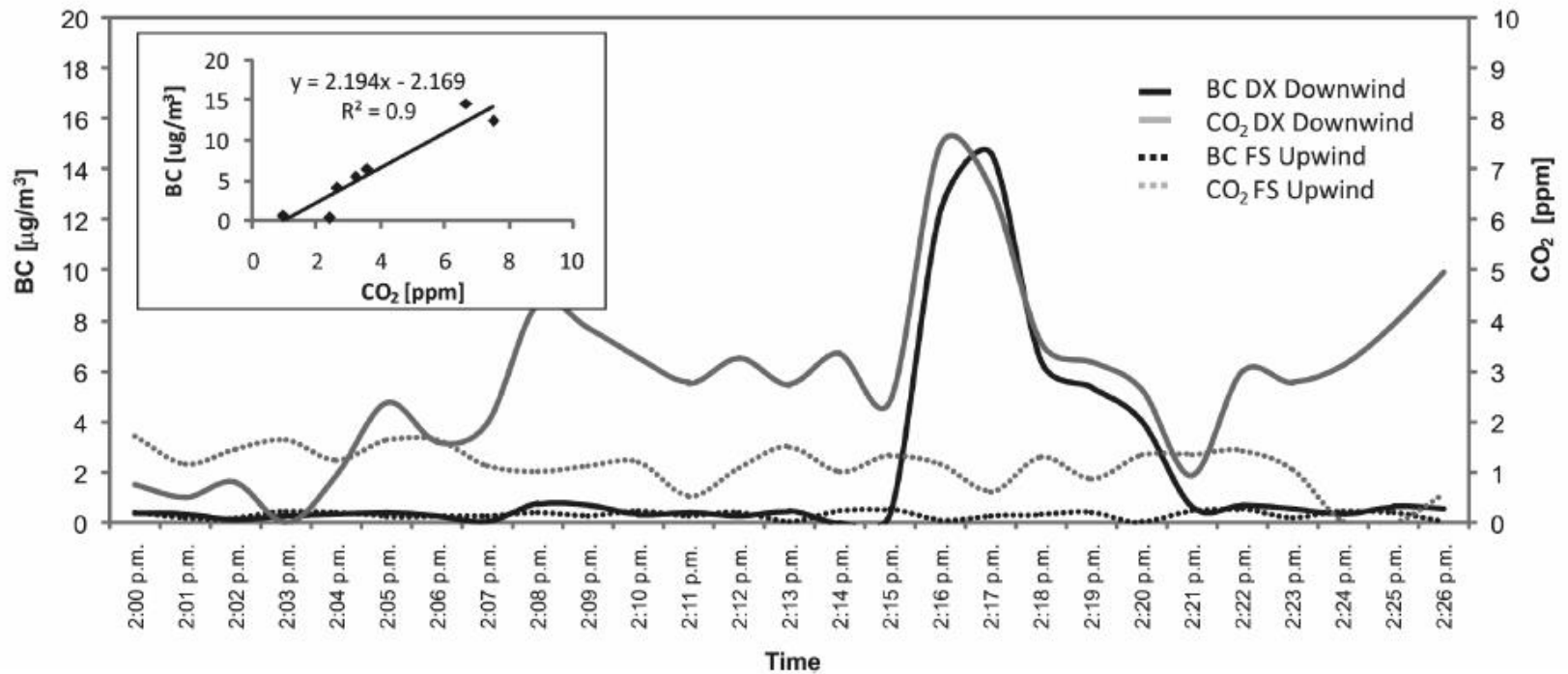
Using Measurements to Estimates Impacts

In-Vehicle Measurements

Noise Dosimeter
sound level

Handheld particle counter
calculated PM2.5 mass

Condensation particle counter
particle number concentration

2-stage Cascade Impactor
coarse and fine mass, metals

PAH meter
particle-bound PAHs

47 mm filter
organic speciation

45.2

15"

8"

21"

25 mm filters
EC/OC, ions, WSOC

Aethalometer
black carbon particles

Manifold for filter holders

(R. Greenwald, Emory Univ.)

BC: In-Vehicle vs. Stationary Site

BC in Atlanta, Georgia on 9/5/2012

BC In Atlanta Rush Hour
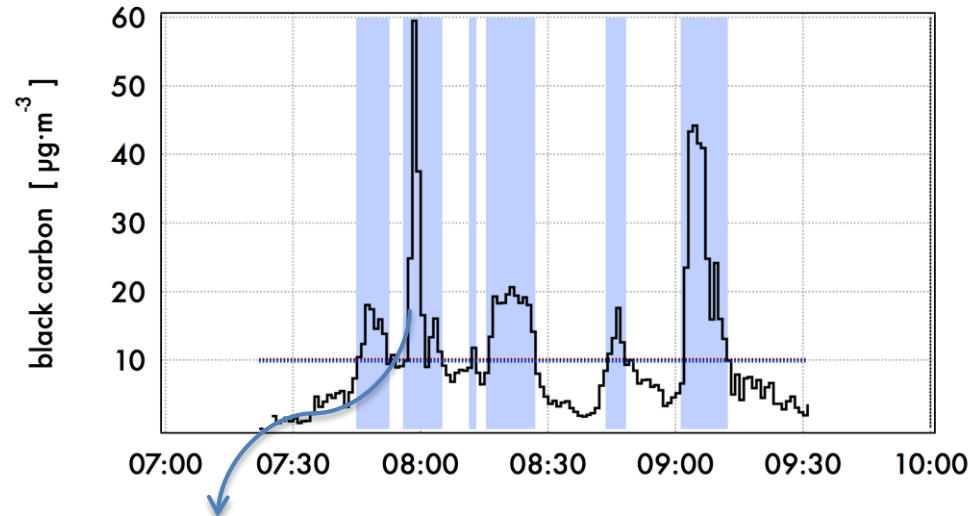
Light Scattering Methods: Single Particle
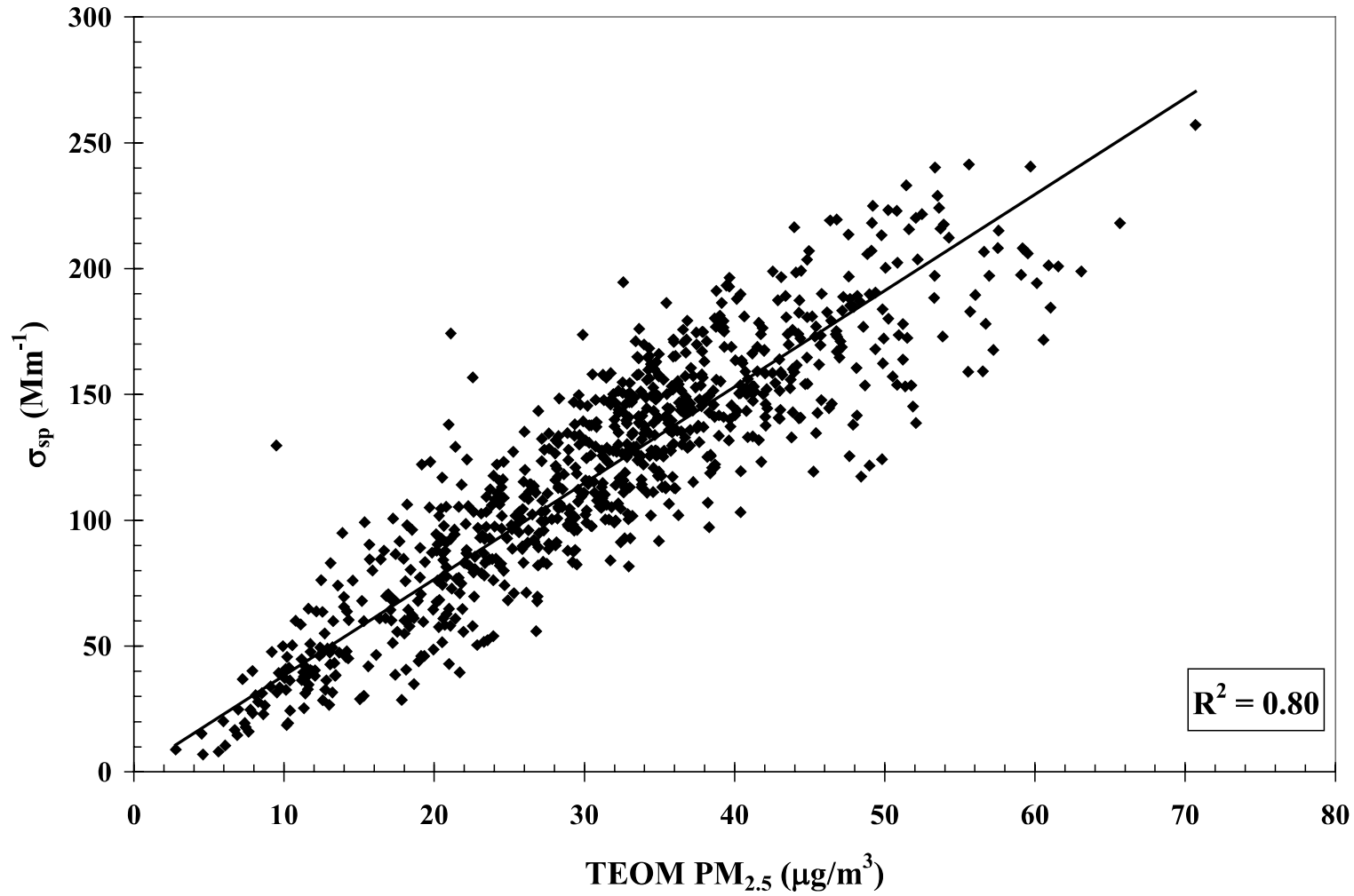
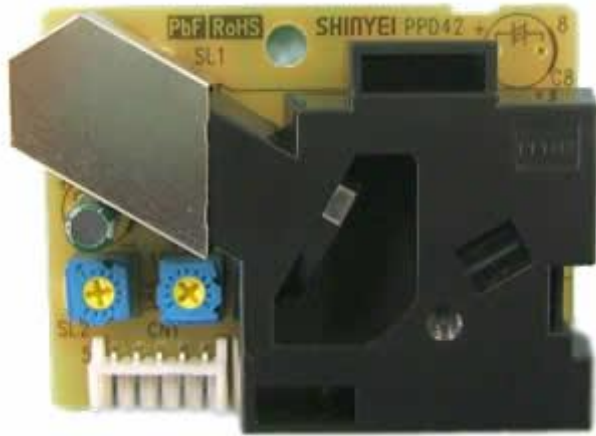Single Particle Counting
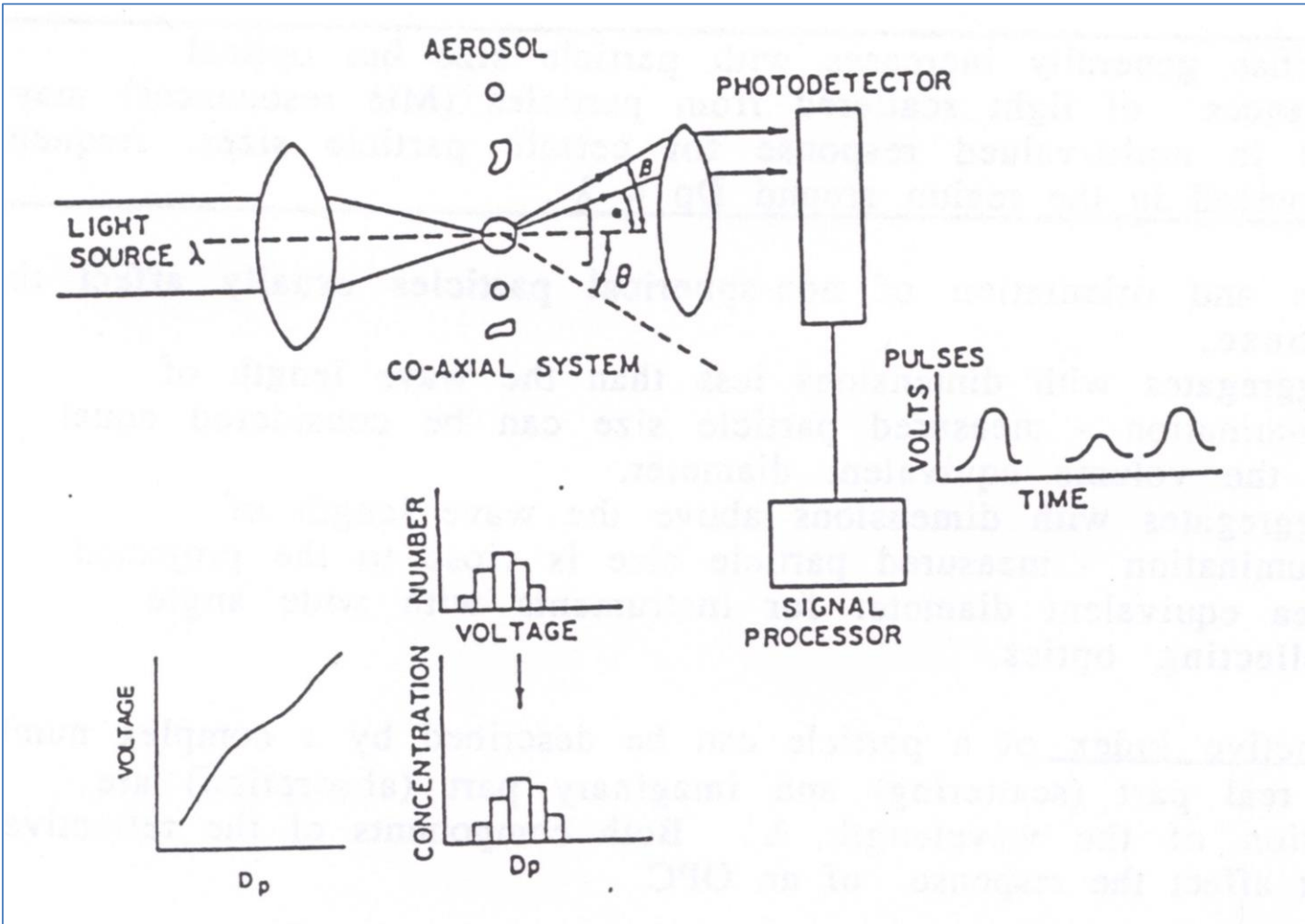
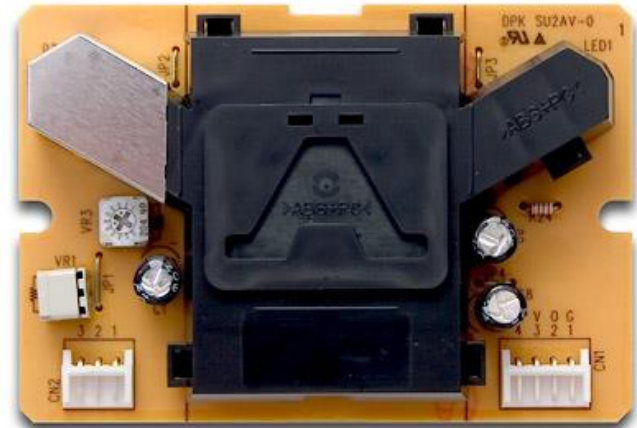# Light Scattering Methods: Volume Scattering

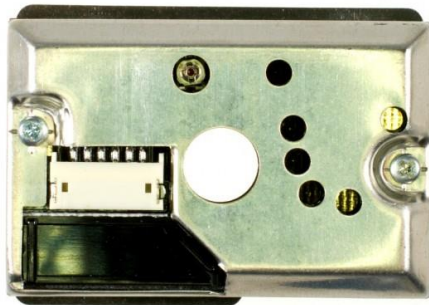Scattering by volume of particles
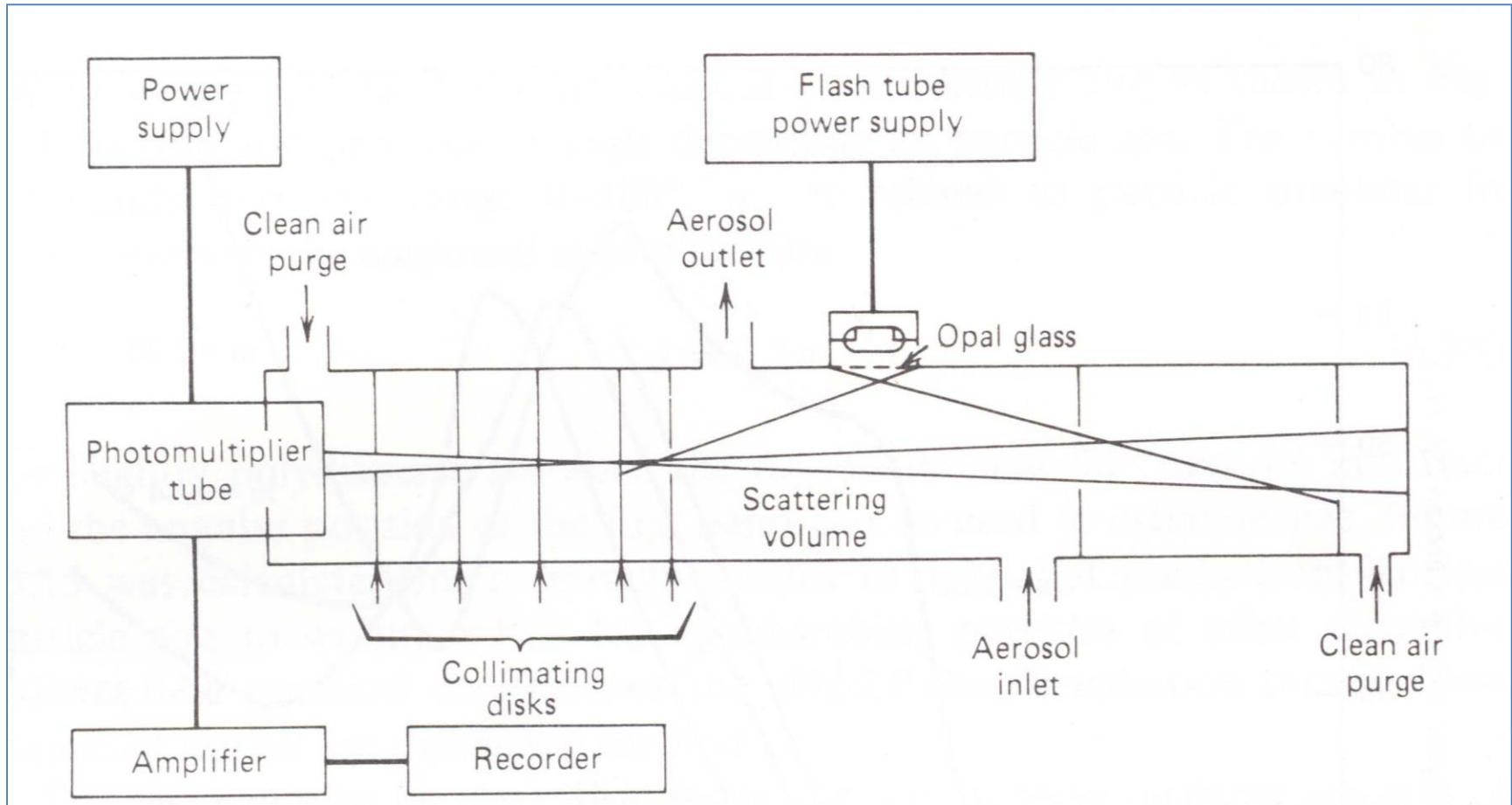
Nephelometer-TEOM Comparison

$R^2 = 0.80$

x-axis: TEOM PM$_{2.5}$ (μg/m^3)

y-axis: σ_{sp} (Mm^{-1})

(Carrico et al., 2003)

Low Cost PM Sensors: Many Options

Shinyei PPD42NS ($20)

Shinyei PPD20V ($350)
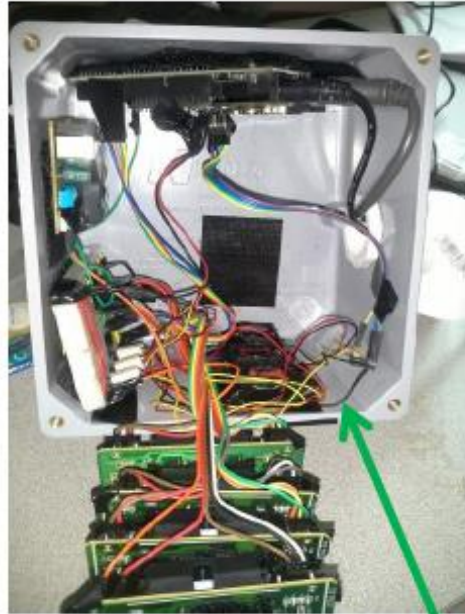

Sharp ($12)

Shinyei PPD60V ($760)

Do They Work?

Low accuracy and precision (no problem):
- Is the air quality in my region bad?
- Is my indoor air filter working?
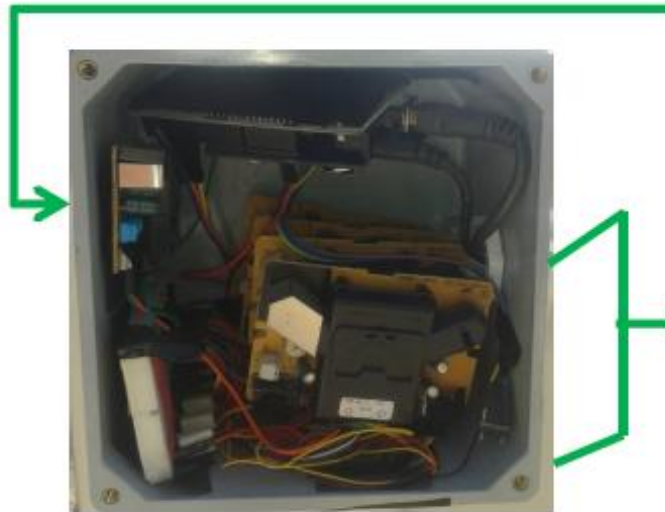- Are their high-emitting sources in my neighborhood?

Higher accuracy and precision (to be determined)?
- What are the specific health impacts of PM?
- Is my region out of EPA attainment?
- What are the source contributions to PM concentrations?

Comparing Sensors, Georgia Tech Roof

1 Shinyei PPD42NS ($20)
- Shinyeidig

3 Shinyei PPD20V($350)
- Shinyei1, Shinyei2, Shinyei3

1 Shinyei PPD60V ($700)
- Shinyei60

3 1" fans to provide air flow through sensors and box

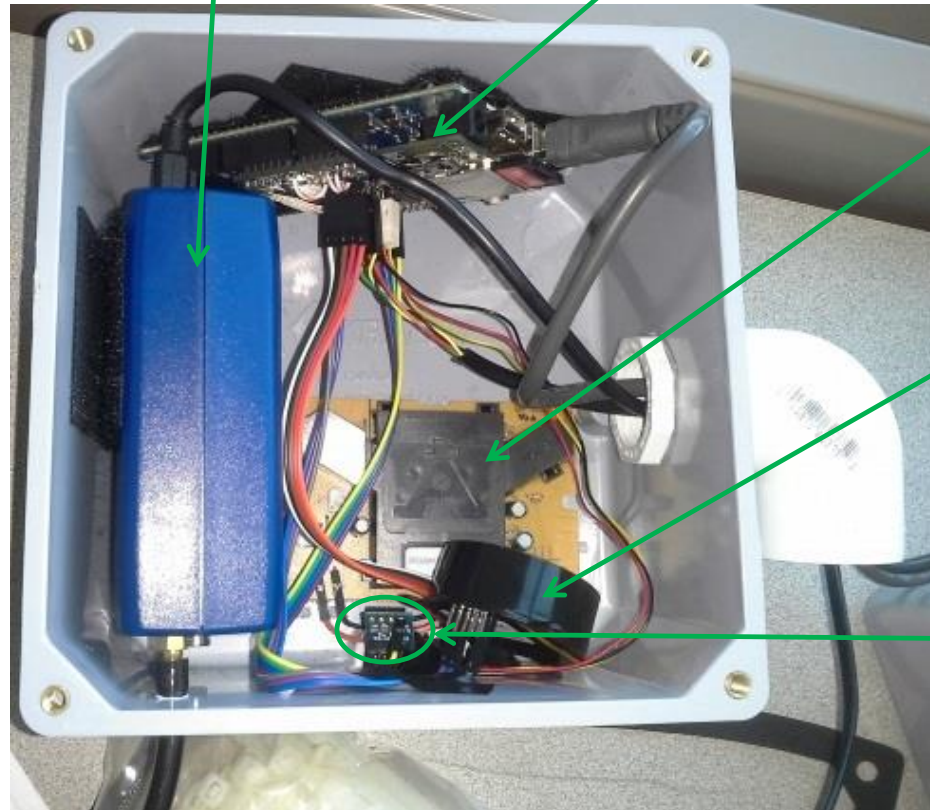# Comparing Sensors: Preliminary Results
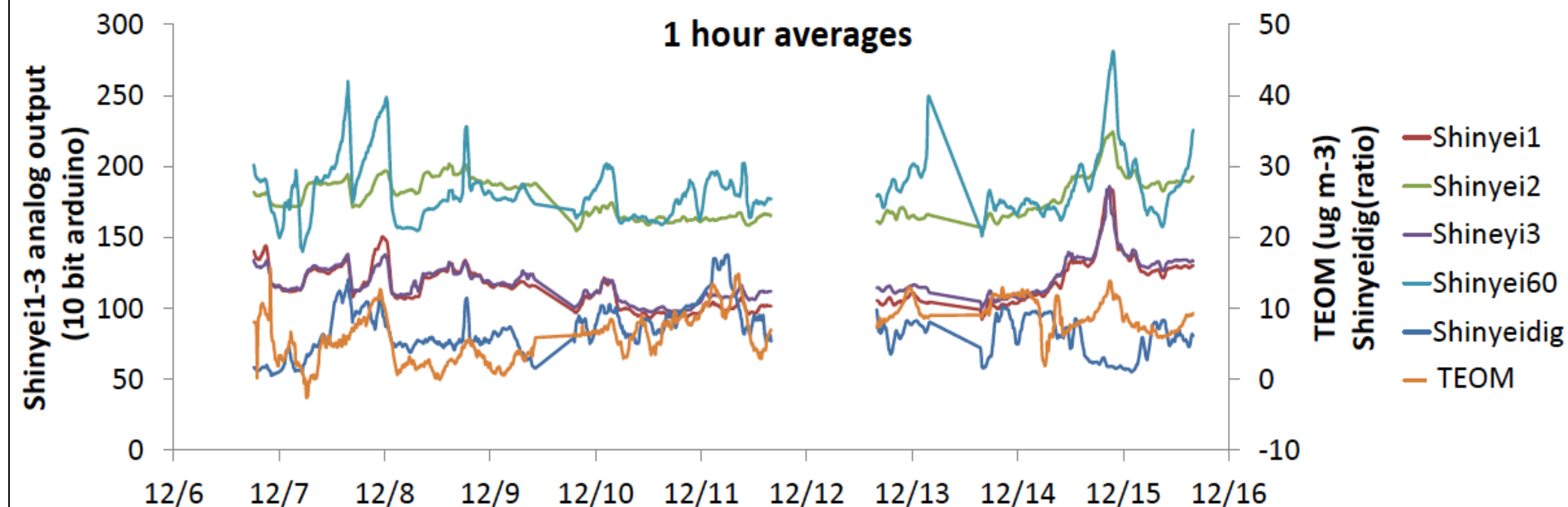
- **Shinyei 1-3 (PPD20V) r^2 = 0.8 - 0.9**
- **r^2 < 0.3 for all Shinyei's and TEOM**

Near Road Low Cost Sensor Evaluation

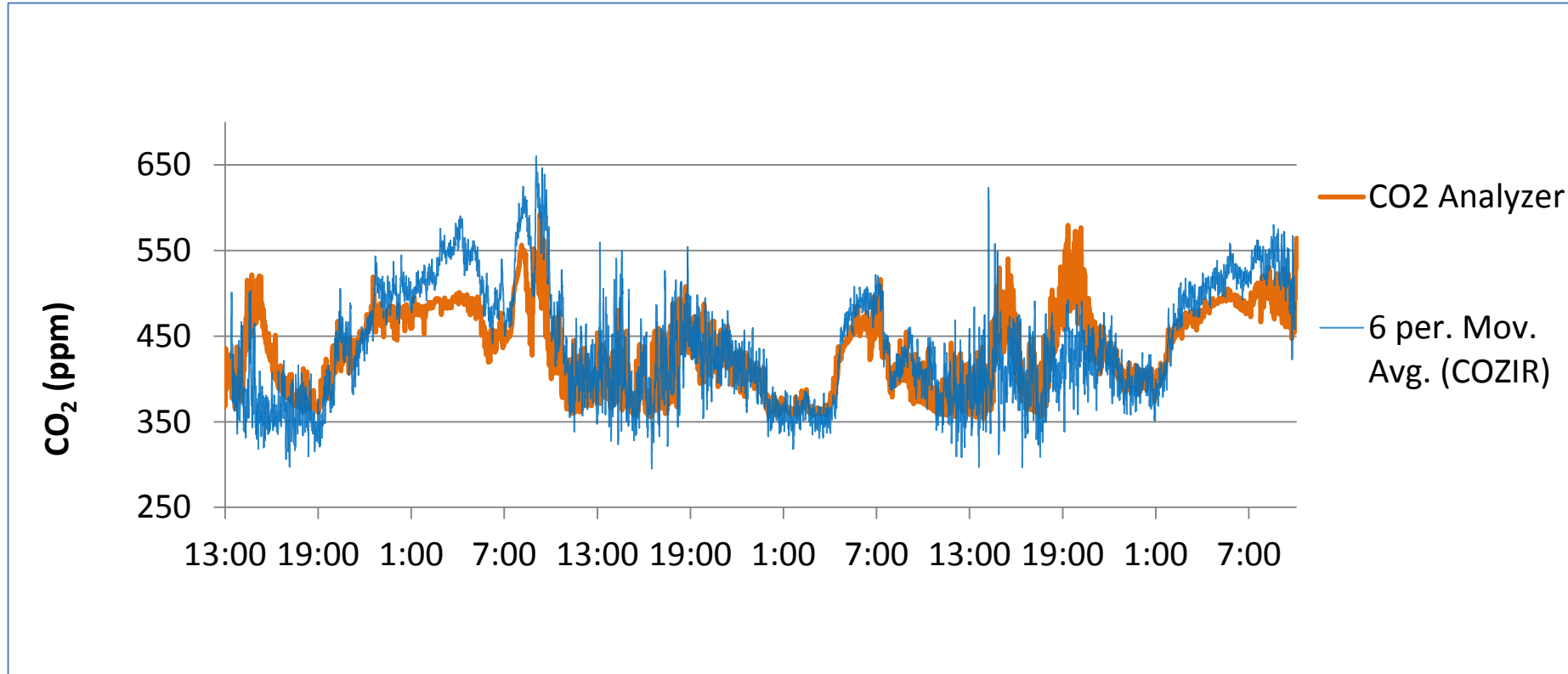microAeth-Black Carbon

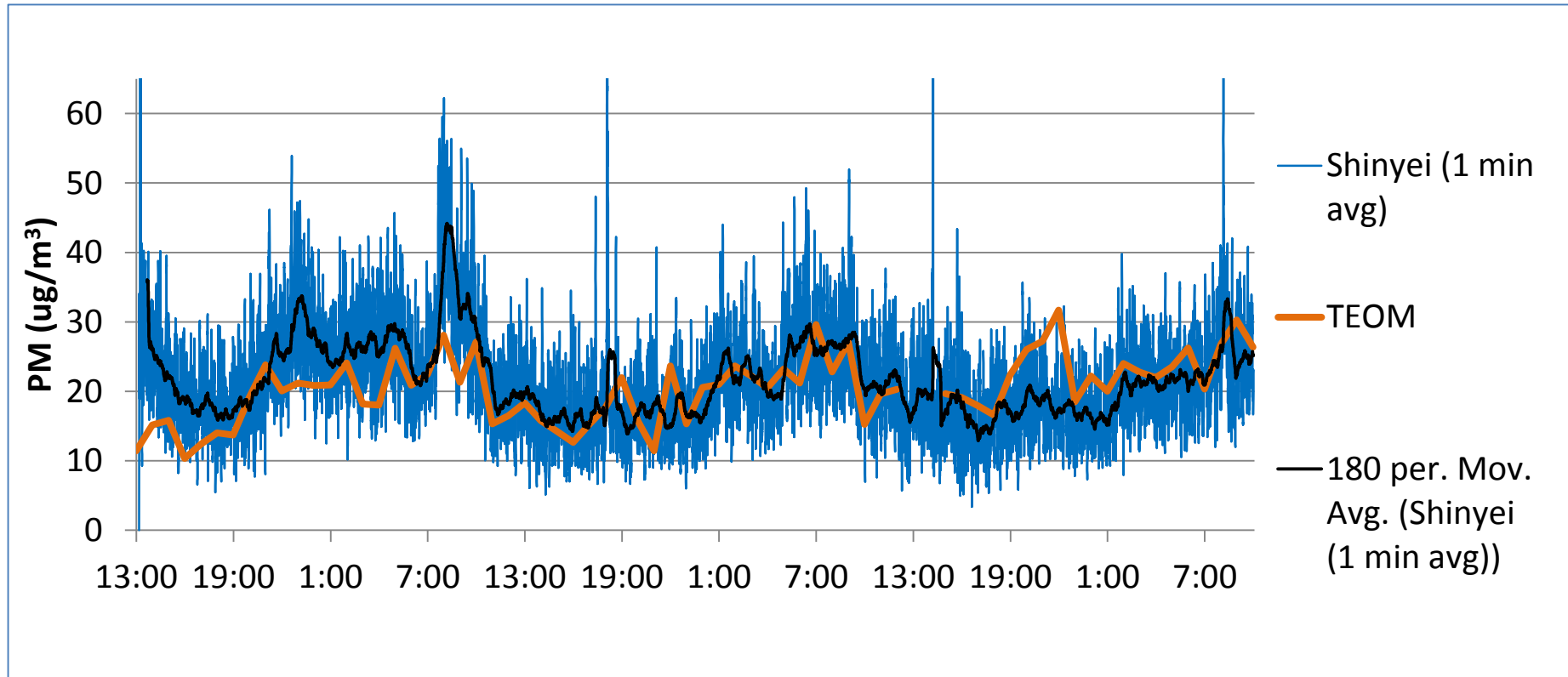Arduino-microcontroler

Shinyei-PM sensor

COZIR-CO_2 Sensor

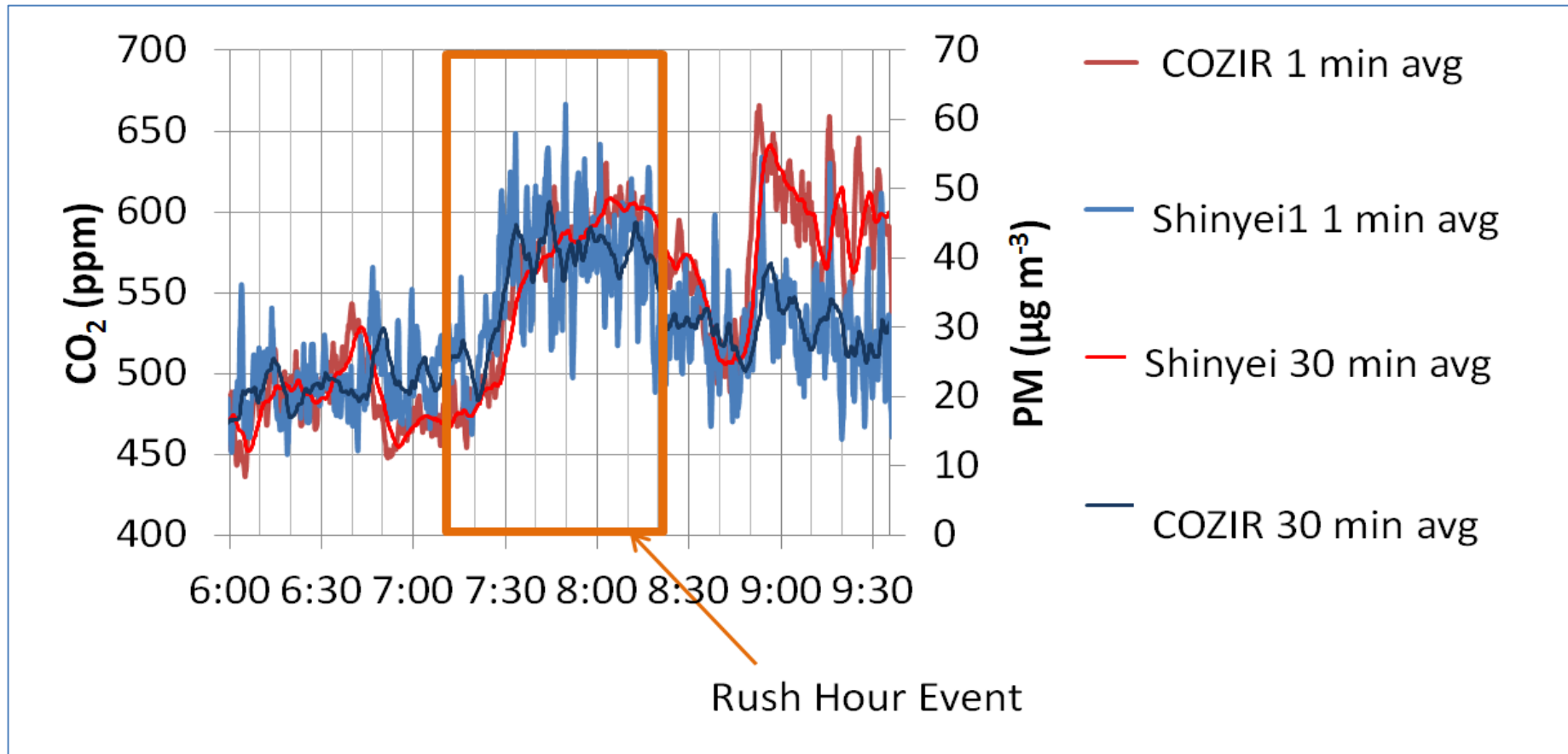temperature and humidity sensor

Atlanta Roadside CO$_2$ Comparisons

- **Thermo 410i CO$_2$ Analyzer (~9k$) and COZIR CO$_2$ (~$100) r^2 = 0.62**

Atlanta Roadside PM Comparisons

- **TEOM (~20k$) and Shinyei Analog (~$300) r² = 0.31, △PM = 3.6 μg m⁻³**
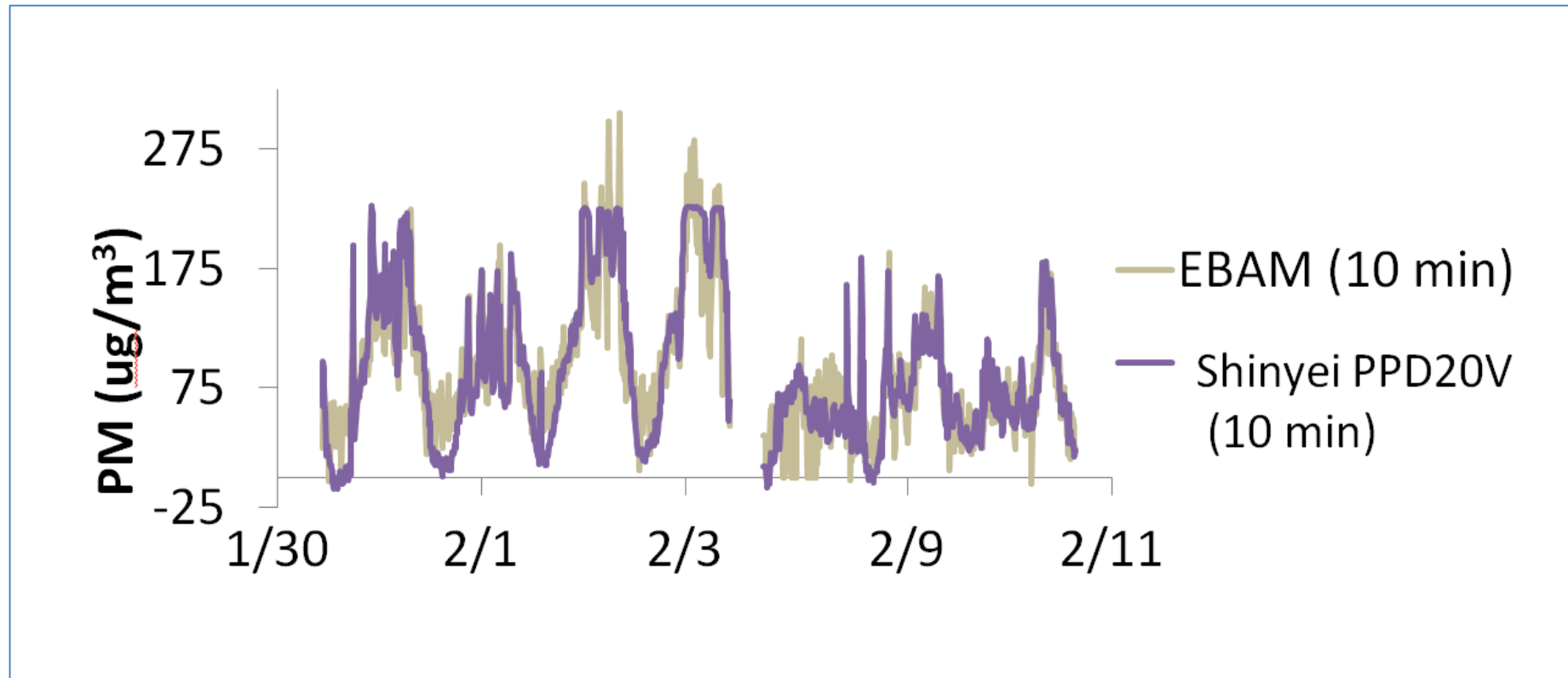
A Low Cost Way to Estimate Emissions Factors (EF)

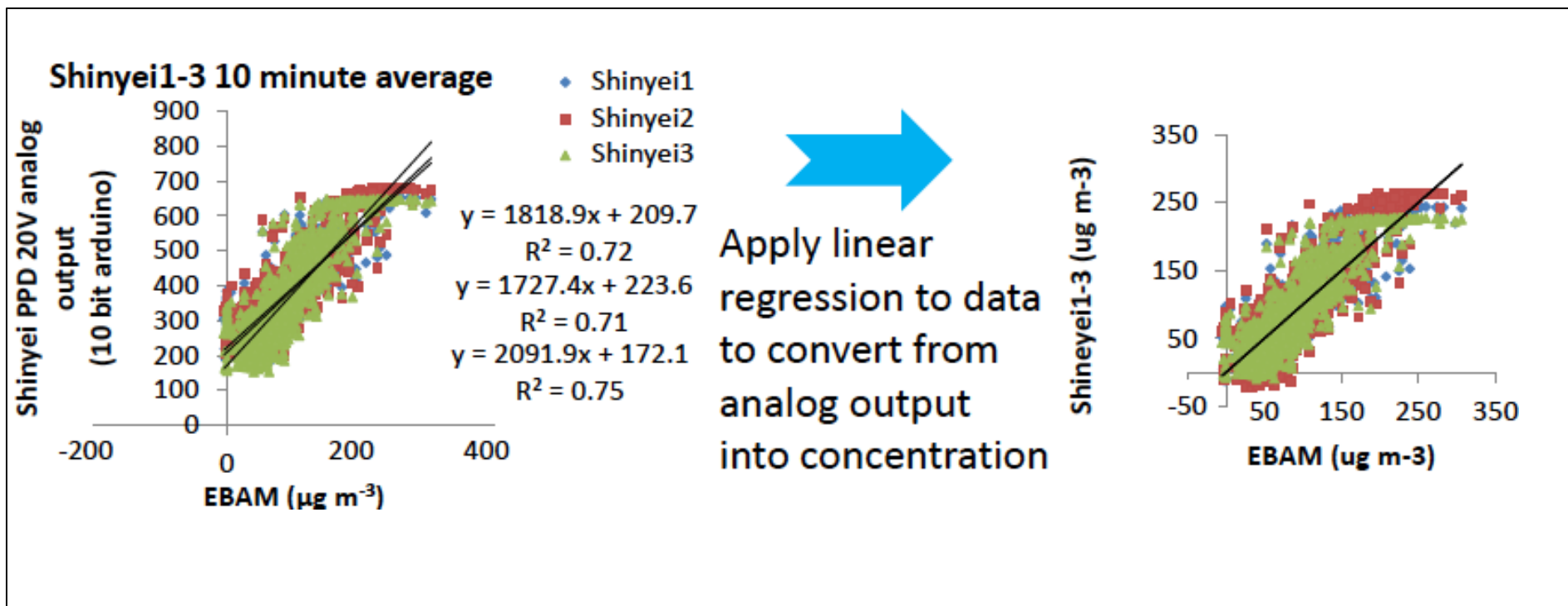- **PM$_{2.5}$ EF = 0.39 g per kg fuel (for ~$500!)**

Hyderabad, India
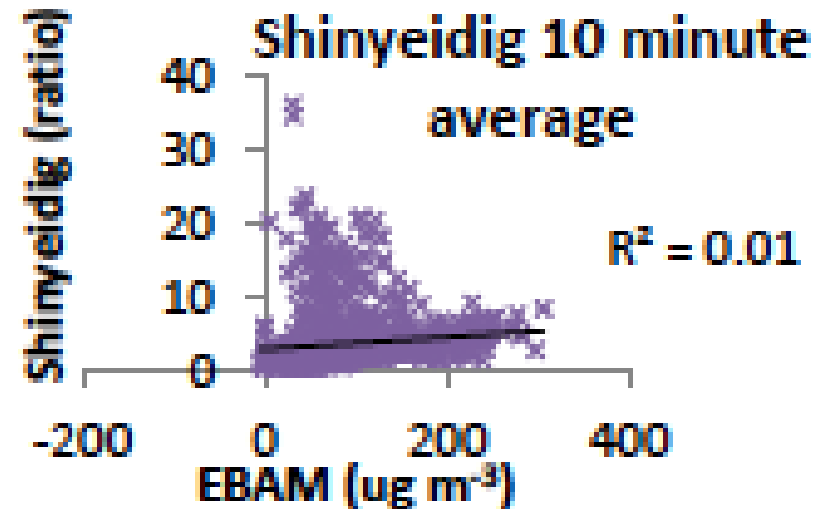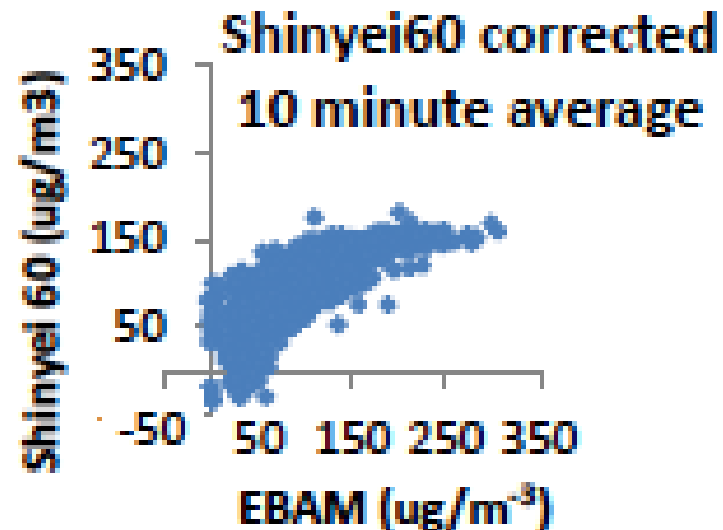
Hyderabad India (High PM) Comparisons

- **EBAM PM$_{2.5}$ (15k\$) and Shinyei (~\$300) r^2 = 0.75**

Estimating High-End Concentrations for Shinyei PPD20V's

Other Sensors Clearly do not work as well!

Work In Progress

- **Further characterization of existing PM sensors both in the lab and field**
- **Development of new sensors for specific applications**
- **Deployment of sensors to form meaningful network of air quality measurements for both public and policy makers**
- **Data QA/QC, management**
- **Integration with modeling framework to develop high resolution temporal and spatial information on air pollutants**

Acknowledgements